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Material - Aluminum - 7075-T651

Effect of Stretching On Mechanical Properties

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6 pages, 2 tables, 1 figure.

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Reference: Bergstedt, P. W., Turner, H. C., Sutherland, W. M., "Effect of Varying Stretch To Produce -T651 Condition in Extruded 7075 Aluminum Alloy Bar Stock," General Dynamics/Convair Report MP 59-214, San Diego, California, 16 November 1959. (Reference attached.)

STRUCTURES-MATERIALS LABORATORIES

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

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REPORT NO. MP-59-214

EFFECT OF VARYING STRETCH TO PRODUCE -T651 CONDITION IN EXTRUDED 7075 ALUMINUM ALLOY BAR STOCK

REA - 8010

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INTRODUCTION:

When aluminum alloys are water-quenched after solution heat treatment, stresses are introduced into the material. Subsequent machining of reasonably straight stock often results in deformed parts; the residual stresses tend to relieve themselves as soon as the balance is disturbed by the machining process. To reduce the residual stress level in flat plate and bar stock, stretch-stress-relieving is commonly employed. This entails stretching the as-quenched, "W" condition, material approximately 1-3/4% immediately after solution heat treatment. Aluminum alloys processed in this manner are now identified by adding "51" to the final temper designation. Thus, stretch-stress-relieved 7075 alloy products would then be listed as 7075-T651 after aging.

Recently, some of the major aircraft companies have proposed that the amount of stretching for stress-relief be raised to a minimum of 2%. Aluminum industry spokesmen have contended that this increase would not benefit the materials, and (since larger machinery would often be required) could result in substantial price increases.

With this controversy in mind, the brief variable-stretch test described herein was undertaken.

OBJECT:

To determine the effect of various amounts of stretching upon the residual stress level and mechanical properties of 7075-T651 aluminum alloy extruded bar.

CONCLUSIONS:

1. Using distortion after machining as a measure of the residual stress level, no significant differences were noted between the effects of the minimum (0.78%) and maximum (2.65%) amounts of stretching employed in this test.

2. The longitudinal tensile properties of variously stretched 7075-T651 extruded bars were reduced 5% to 10% with the greater losses occurring in the more highly stretched bars. Yield and ultimate strength losses were nearly identical; however, elongation was not noticeably affected.

3. Compression yield strength was also reduced by stretching in the "W" condition. The losses closely paralleled those observed for tensile strength, but the 2.65% stretch appeared to effect partial recovery from the maximum loss at 1.94% stretch.

PROCEDURE:

Four 60-inch-long bars were cut from a single 7075-T6 extrusion with a 1"x1-1/4" cross-section. Following re-solution heat treatment (95 minutes minimum soak at 870°F), the bars were water quenched and immediately submitted for straightening and stretching operations. The initial stretch-straightening was measured over a 48-inch gauge length; the final stretching for stress-relief was checked against a new 48-inch gauge length laid out in 6-inch increments. All of the straightening and/or stretching was completed within one hour after solution heat treatment, and the bars were then aged at 250°F for 24 hours.

Each bar was then clamped in turn to one end of a steel bar which had been carefully marked at 6-inch intervals. A mating set of marks were scribed upon the aluminum bar, and the distances between the marks on the two bars were measured to the nearest 0.01 inch. One-fourth of an inch of material was then machined from one side of each aluminum bar — the side away from the steel reference bar when measurements were made. (See Figure 1) Each bar was then re-clamped to the reference bar, and the distances between the marks were re-measured. Differences between the two sets of measurements were used to evaluate stress-relief in terms of relative amount of distortion after the machining operation.

When distortion variations of the stretched bars were found to be slight, a fifth bar was obtained for control purposes. No stretch loads were applied to this bar; it was simply hand-straightened immediately after re-solution heat treatment. The bar was then aged and subjected to the distortion check described above.

To investigate the effect of variable stretching upon the mechanical properties of the test material, three tensile specimens and three compression specimens were prepared from each of the 48-inch test-sections. Tensile specimens were 0.505" D. threaded bars, Type R1, as described in Federal Test Method Standard No. 151. Compression specimens were cylindrical, 0.798" D. x 2.375", prepared in accordance with ASTM Standard E9-33T. Standard laboratory practice was followed in testing the specimens.

RESULTS & DISCUSSION:

The distortion check (Fig. 1 and Table I) was borrowed from Engineering Test Laboratory Report No. 4844, published in November, 1946. That report proved the efficacy of the now-accepted technique of stretching freshly quenched material 1-3/4% to relieve residual stresses. However, the fact that straightening was accomplished by bending was not stated; when, in the present test, stretch-straightening required a measurable permanent set (1/2 to 3/4%) and significantly affected the distortion measurements, a "control" bar was necessitated that had simply been hand-straightened.

RESULTS & DISCUSSION: (Continued)

There is no guarantee that the control bar was cut from the original extrusion, and heat treat variables (within accepted tolerances) may have had some effect upon the distortion characteristics and the mechanical properties of this bar.

With regard to the problem at hand, the test showed that no apparent advantage was to be derived from increasing the amount of stretching to 2% for stretch-stress-relieving. In fact, if one were to take the results shown in Tables I and II at face value, strong arguments can be advanced in favor of lowering the required amount of stretching. The 0.78% stretch compared very well with the 1.74% stretch, and the mechanical property losses of these bars were not as great as those for the more highly stretched bars.

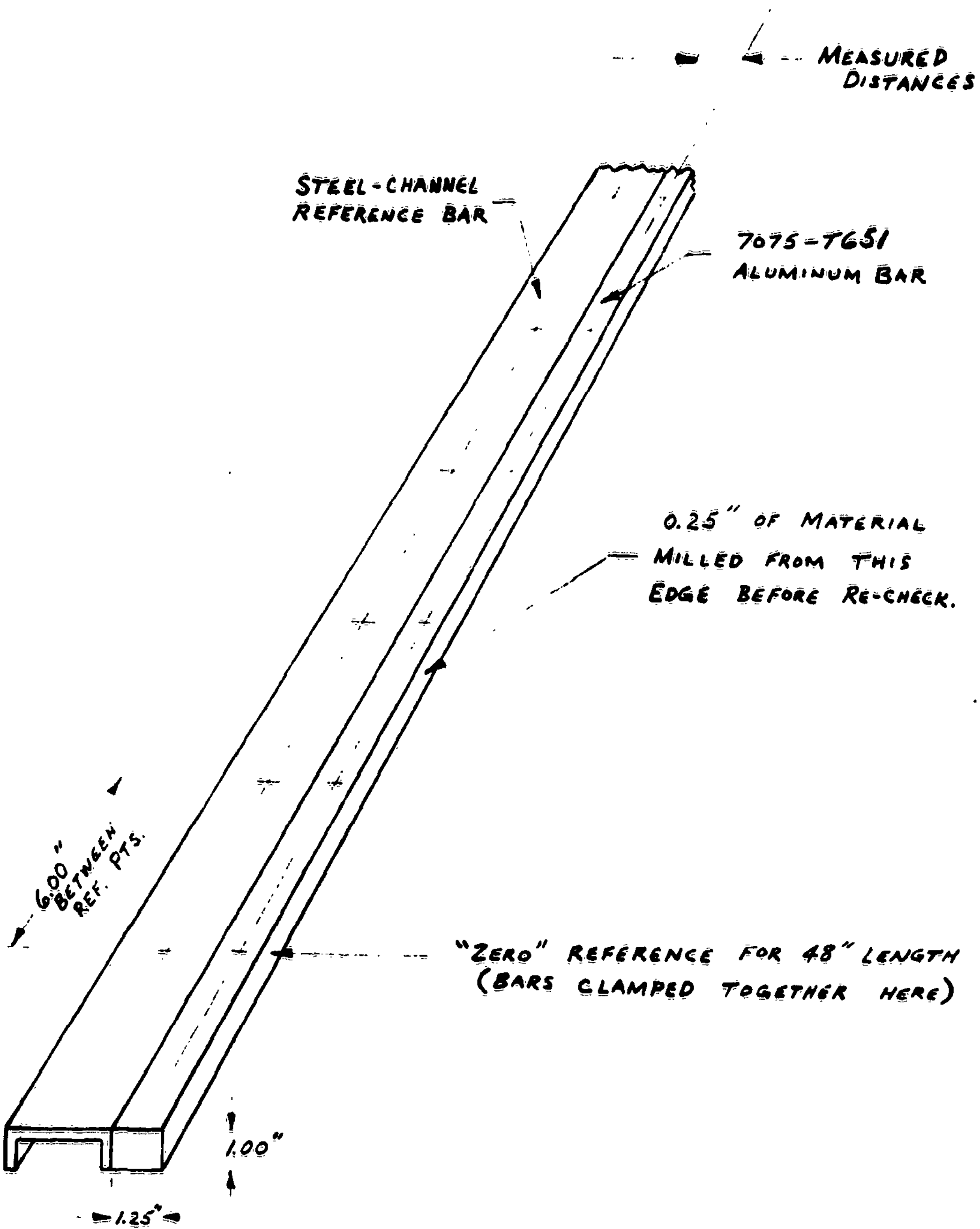

FIG. 1. METHOD OF MEASURING DISTORTION TO COMPARE RESIDUAL STRESSES IN STRETCHED 7075-T651 BARS

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TABLE I. COMPARATIVE DISTORTION OF 7075-T6 ALUMINUM EXTRUDED BARS VARIOUSLY STRETCHED IN THE "W" CONDITION

Processing Schedule After Re-Solution Heat Treatment	Percent Permanent Set: Straightening	Stress Relief	Total	Reference Measurements Taken Before and After Machining – Distance from Clamp Point →	0"	6"	12"	18"	24"	30"	36"	42"	48"		Reduction of Distortion Due to Stretching
"Control" Bar. Bent straight, aged, and checked for relative distortion by the machining method	—	—	—	Before Mchg.	1.50	1.60	1.49	1.50	1.50	1.59	1.59	1.59	1.59		
				After Mchg.	1.50	1.61	1.56	1.65	1.78	2.05	2.24	2.47	2.72		
				Net Defl.	0	0.01	0.07	0.15	0.28	0.46	0.65	0.88	1.13	→	"Control"
Stretch straightened only, aged, and checked for relative distortion by the machining method.	0.78	—	0.78	Before Mchg.	1.59	1.60	1.60	1.60	1.61	1.61	1.61	1.62	1.62		
				After Mchg.	1.59	1.60	1.61	1.63	1.65	1.69	1.72	1.76	1.82		
				Net Deflection	0	0	0.01	0.03	0.04	0.08	0.11	0.14	0.20	→	82 %
Stretch straightened, stretch stress relieved (1%), aged, and checked for relative distortion.	0.78	0.96	1.74	Before Mchg.	1.60	1.60	1.60	1.61	1.62	1.62	1.62	1.62	1.62		
				After Mchg.	1.60	1.60	1.62	1.64	1.67	1.71	1.76	1.80	1.87		
				Net Deflection	0	0	0.02	0.03	0.05	0.09	0.14	0.18	0.25	→	78 %
Stretch straightened, stretch stress relieved (1½%), aged, and checked for relative distortion.	0.52	1.42	1.94	Before Mchg.	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60		
				After Mchg.	1.60	1.60	1.61	1.63	1.64	1.66	1.69	1.72	1.76		
				Net Deflect.	0	0	0.01	0.03	0.04	0.06	0.09	0.12	0.16	→	86 %
Stretch straightened, stretch stress relieved (2%), aged, and checked for relative distortion.	0.65	2.00	2.65	Before Mchg.	1.59	1.59	1.60	1.60	1.60	1.61	1.62	1.62	1.62		
				After Mchg.	1.59	1.60	1.61	1.63	1.65	1.67	1.73	1.77	1.82		
				Net Deflect.	0	0.01	0.01	0.03	0.05	0.06	0.11	0.15	0.20	→	82 %

TABLE II. EFFECT OF STRETCHING 7075-W EXTRUDED BAR TO RELIEVE QUENCH-STRESSES.

Processing Schedule After Solution Heat Treatment	Maximum Deflection After Machining 1/4" From 1 1/4" Dimension (One Side) of 1"x1 1/4"x48" Bar, Fully Aged		Tensile Properties: Fty, psi 0.2% offset	Tensile Properties: Ftu, psi	Tensile Properties: % Elong., 2" Gauge	Compression Fcy, psi 0.2% offset
Bent Straight, Then Aged. No Stretch	1.13 inch		87,700	96,300	10.0	88,600
			86,700	95,400	12.0	89,000
			87,000	95,800	11.0	88,600
		Avg:	87,100	95,800	11.0	88,700
Stretched 0.78% in "W" Condition, Then Aged.	0.20 inch		82,300	90,500	11.0	83,700
			84,200	90,200	11.0	83,500
			82,100	90,100	11.0	84,100
		Avg:	82,900	90,300	11.0	83,800
Stretched 1.74% in "W" Condition, Then Aged	0.25 inch		83,100	90,100	10.5	83,500
			82,500	90,500	10.5	82,900
			82,000	90,500	11.0	82,000
		Avg:	82,500	90,400	10.7	82,800
Stretched 1.94% in "W" Condition, Then Aged	0.16 inch		80,100	87,600	11.0	80,200
			78,400	87,400	11.0	80,100
			81,000	87,600	11.0	80,400
		Avg:	79,800	87,500	11.0	80,200
Stretched 2.65% in "W" Condition, Then Aged	0.20 inch		79,900	87,900	10.5	81,300
			— Specimen improperly mach'd. —			82,100
			79,600	86,800	10.5	83,700
		Avg:	79,800	87,400	10.5	82,400